

AI-Powered USB Handbook

USB

AI-Powered USB Handbook Team

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1. AI-Powered USB Handbook

AI-Powered USB Handbook

AI-Powered USB Handbook	USB	USB 3.2 Gen 2x2	Thunderbolt 4 (4)
Type-C			

1.1

- -
- **USB** - USB
- **USB** -
- **Thunderbolt** -
- - USB PD
- -

1.2

-
-
-
-

2. 1 (Introduction)

2.1

USB (Universal Serial Bus) Type-C

USB

USB 3.2 Gen 2x2

AI-Powered USB Handbook

USB

AI

2.2

- 4 USB4
 - USB

2.3

- 1.
 2. USB 1.0 USB4
 3. Intel Thunderbolt USB
 4. USB PD PPS
 - 5.

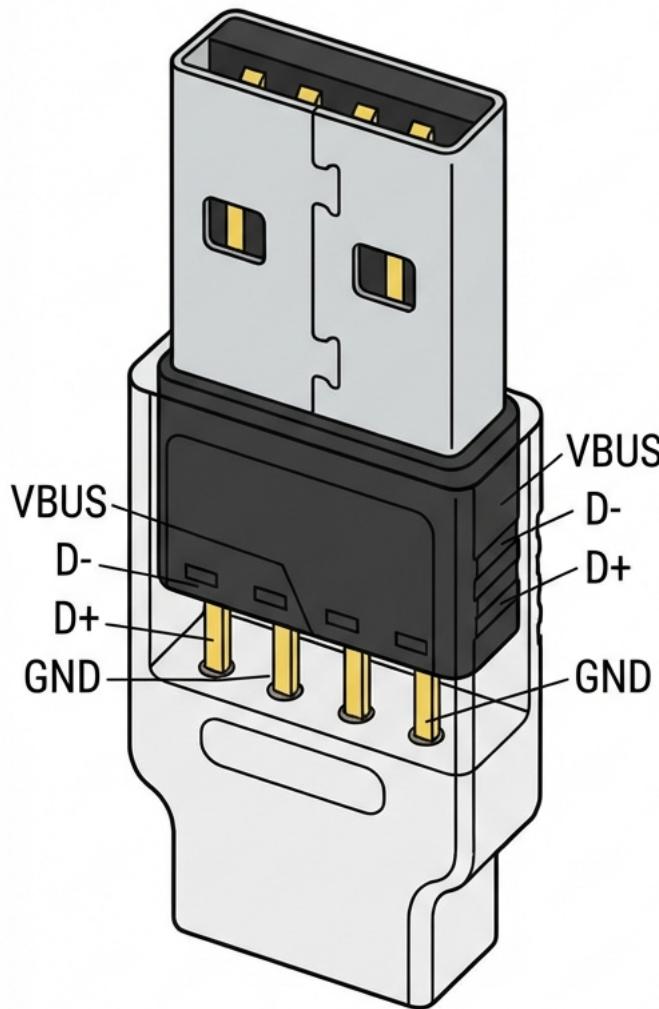
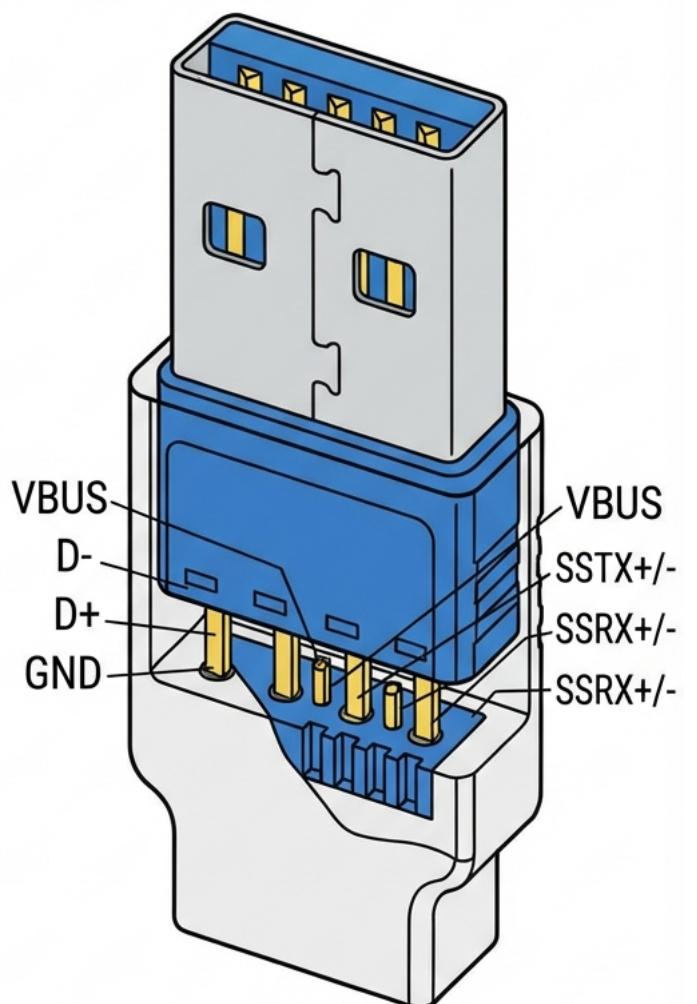
3. 2 USB (USB Connector Types)

USB

3.1 USB Type-A

USB

-
-
- **USB 2.0** 4
- **USB 3.0+** 5 9

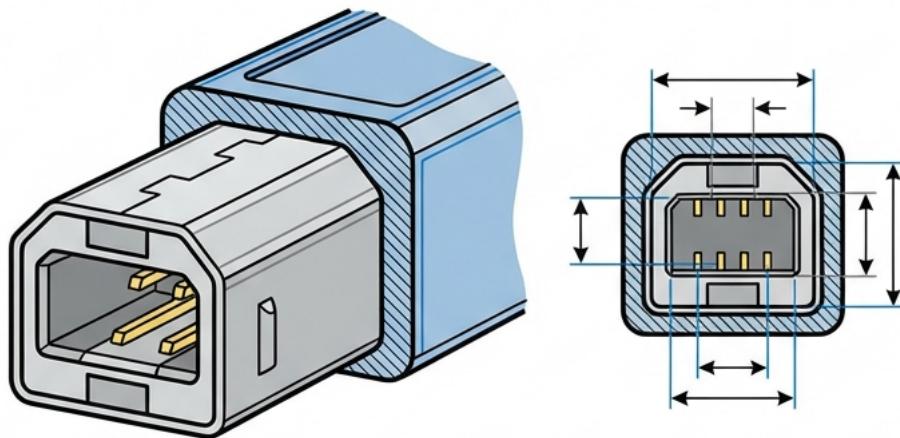
USB 2.0 Type-A**USB 2.0 Type-A****USB 3.0 Type-A
(SuperSpeed)****USB 3.0 Type-A
(SuperSpeed)**

3.2 USB Type-B

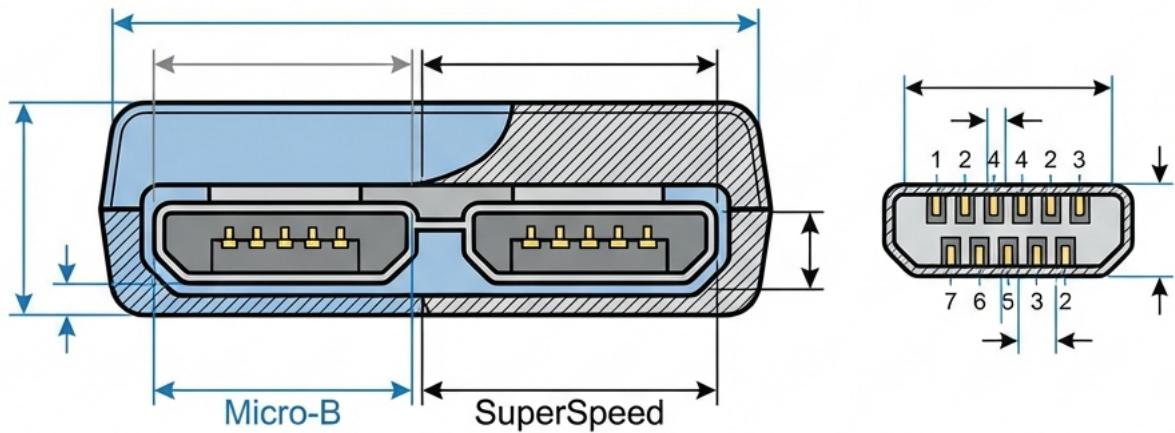
- Standard-B
- Micro-B (USB 3.0)

Elements

USB 3.0



**USB Standard-B
(Printer)**

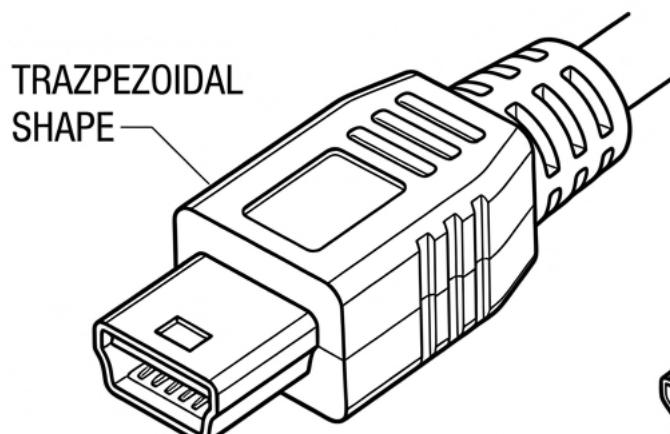


**USB Micro-B SuperSpeed
(External HDD)**

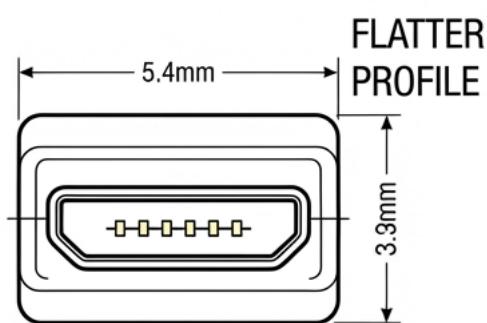
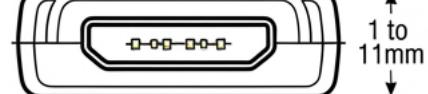
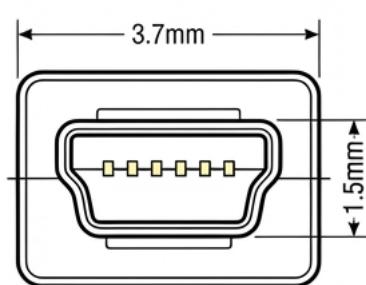
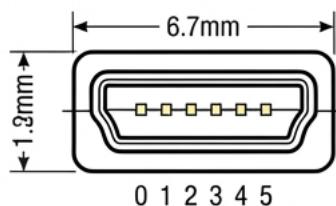
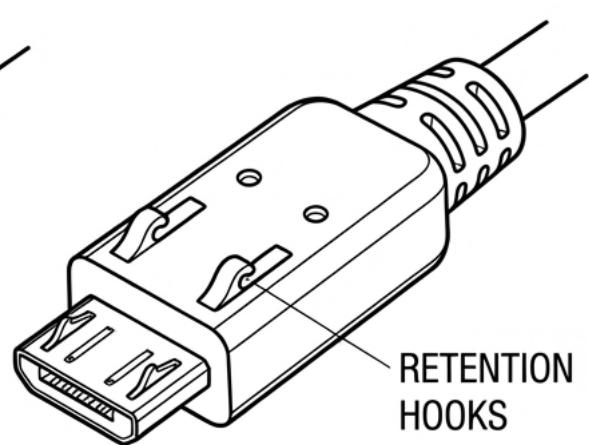
3.3 Mini USB & Micro USB

- **Mini USB** MP3
- **Micro USB** USB 2.0

MINI USB



MICRO USB



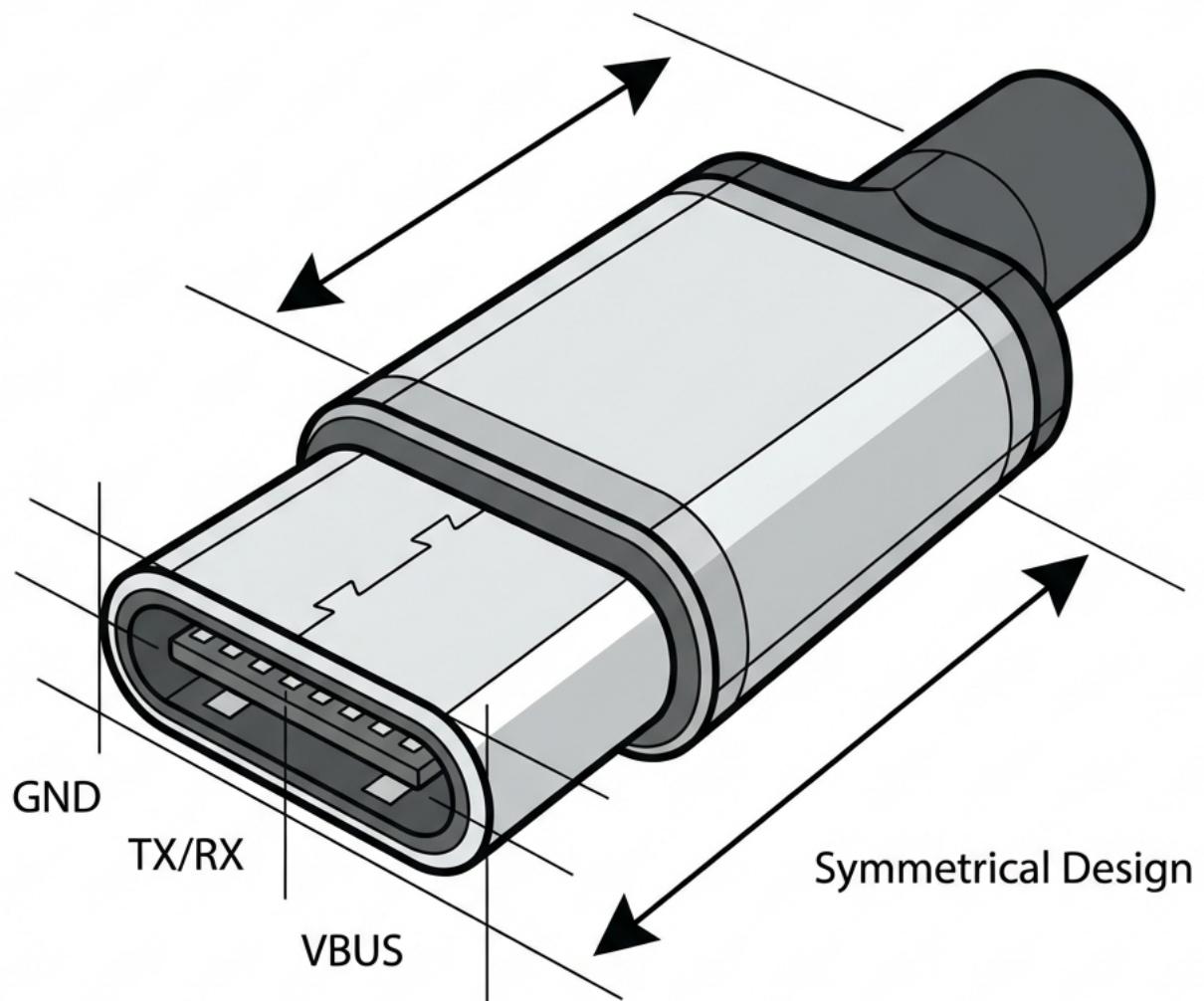
MINI USB

MICRO USB

3.4 USB Type-C

- DP Alt Mode 240W USB PD
- 24 22 CC (Configuration Channel)
- **Type-C** Type-C USB 2.0

4



4. 3 USB (USB Transfer Protocols)

USB USB-IF (USB)

4.1

- **USB 1.0 / 1.1:**
- **Low Speed:** 1.5 Mbps ()
- **Full Speed:** 12 Mbps
- **USB 2.0:**
- **High Speed:** 480 Mbps " "

4.2 USB 3.x

	(2013)	(2019)			
USB 3.0	USB 3.1 Gen 1	USB 3.2 Gen 1	USB 3.0 / 5Gbps	5 Gbps	8b/10b
N/A	USB 3.1 Gen 2	USB 3.2 Gen 2	USB 3.1 / 10Gbps	10 Gbps	128b/132b
N/A	N/A	USB 3.2 Gen 2x2	USB 3.2 / 20Gbps	20 Gbps	128b/132b

USB 3.2 Gen 2x2 Type-C Type-C

4.3 USB4

USB4 Intel Thunderbolt 3

- **USB4 Gen 2x2:** 20 Gbps
- **USB4 Gen 3x2:** 40 Gbps ()
-
- **(Tunneling)** (USB 3.2) (DisplayPort) PCIe
- USB 3.2 USB 2.0 Thunderbolt 3

5. 4 Thunderbolt () (Thunderbolt Technology)

Thunderbolt Intel Apple " " " "

5.1 Thunderbolt 3 (3)

- USB Type-C
- 40 Gbps
- PCIe x4 () DisplayPort (5K/8K) USB
- 3 USB 3.x USB

5.2 Thunderbolt 4 (4)

4 40 Gbps

5.2.1 4 vs 3

1. PCIe	4 PCIe	32 Gbps (3 16 Gbps)	(eGPU)	SSD
2.	4 4K	8K (3 4K)		
3.	Intel VT-d DMA	DMA		
4.	4 (Hub)	1 3 3	(Daisy Chain)	

5.3 Thunderbolt vs USB4

- USB4 3
-
- **USB4** " " 20Gbps 40Gbps PCIe
- **Thunderbolt 4** " " 40Gbps PCIe Intel
- **Thunderbolt 4 USB4** " "

6. 5 (Charging & Power Delivery)

USB 2.5W (5V 0.5A) 240W

6.1

6.1.1 USB BC 1.2 (Battery Charging)

USB BC 1.2 USB-IF 2010

- 7.5W (5V 1.5A)
- D+/D-
-
- **SDP (Standard Downstream Port)** USB 500mA
- **CDP (Charging Downstream Port)** + 1.5A
- **DCP (Dedicated Charging Port)** 1.5A
-

6.2

6.2.1

2010

- **USB 2.0** USB **2.5W** (5V 0.5A) 4-6
- **USB BC 1.2** 7.5W (5V 1.5A)
- USB PD 1.0 2012 2016 PD 3.0
-
- " 5 2 "
-
- 2013-2016 USB PD

OPPO " "

[!IMPORTANT]

6.2.2

```
timeline
  title
  2010 : USB BC 1.2 (7.5W) :
  2012 : USB PD 1.0 :    PD    <br>
  2013 :    QC 1.0 (10W) :
  2014 :    QC 2.0 (18W) :
  : OPPO VOOC (20W) :
  2015 :    FCP (18W) :
  :        PE+ : MTK
  2016 :    QC 3.0 : 200mV
  :        SCP (22.5W) :    <br>
  : USB PD 3.0 :
  : vivo      (22.5W)
  2017 :    PE 3.0 (30W)
  :        QC 4 :    USB PD
  2018 : OPPO SuperVOOC (50W) :
  :        (27W)
  :        QC 4+
```

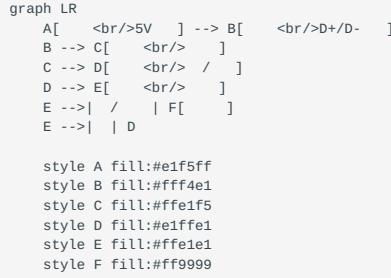
```

2019 : OPPO SuperVOOC 2.0 (65W)
    :     SCP 2.0 (40W)
2020 :     QC 5 (100W+) :     PD
    :     (120W)
2021 : OPPO 125W/240W :
    :     (210W)
    : vivo (200W)
2023 :     Type-C :

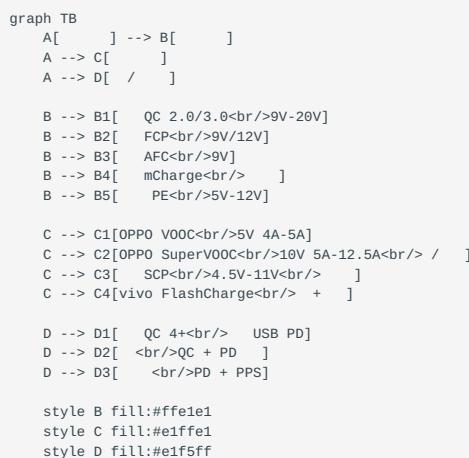
```

6.2.3

Handshake Protocol



1. 5V
 2. D+/D-
 - 3.
 4. /
 - 5.
- [!NOTE] D+/D- USB " " "



6.2.4 Quick Charge (QC)

Quick Charge

Android

QC 1.0 (2013)

- 10W (5V 2A)

-
-

QC 2.0 (2014)

QC 2.0

- 18W
-
- Class A: 5V 9V 12V
- Class B: 5V 9V 12V 20V
- 3A
- D+/D-
- 5V D+ = D- = 0.6V
- 9V D+ = 3.3V, D- = 0.6V
- 12V D+ = 0.6V, D- = 0.6V
- 20V D+ = 3.3V, D- = 3.3V Class B

QC 3.0 (2016)

QC 3.0

- 18W 22W
- 3.6V - 20V
- **200mV** QC 2.0
-
-
- **38%** QC 2.0
-
- QC 2.0

QC 4 / QC 4+ (2017-2018)

QC 4/4+ USB PD

- 28W (QC 4) 100W (QC 4+)
-
- **USB PD 3.0** PD
- **PPS (Programmable Power Supply)**
- **INOV (Intelligent Negotiation for Optimum Voltage)**
- QC USB PD
-

QC 5 (2020)

- **100W+**
- 98%

• USB PD QC	[!IMPORTANT] QC 4	USB PD	QC 4+	PD	iPhone MacBook
-------------	-------------------	--------	-------	----	----------------

6.2.5 OPPO VOOC

OPPO VOOC

VOOC (2014)

- 20W
- / **5V 4A**
-
- QC 5V 4A-5A
- 7 Micro-USB 5 2
-
- **MCU ()**
-
-
-
-

SuperVOOC (2018)

SuperVOOC

- 50W
- / **10V 5A**
-
- 2000mAh
- 10V 5V
- 5V 10V 5A
-

SuperVOOC 2.0 (2019-2020)

- 65W
- / **10V 6.5A**
- OPPO Find X Reno

125W / 240W (2021-)

OPPO - 125W 10V 12.5A	- 240W 24V 10A	OPPO	Type-C	VOOC
------------------------------	-----------------------	------	--------	------

6.2.6 FCP / SCP

FCP (Fast Charge Protocol, 2015)

- 18W
- 9V / 12V
- 2A
- D+/D-
-

SCP (SuperCharge Protocol, 2016)

SCP	VOOC	SCP	FCP	FCP	FCP	SCP
•						
• SCP 1.0 22.5W (5V 4.5A 4.5V 5A)						
• SCP 2.0 40W (10V 4A)						
• SCP 3.0 66W (11V 6A)						
•						
•						
•						
•						
• FCP						
[!NOTE] FCP SCP		SCP	FCP	FCP	FCP	SCP

6.2.7 Pump Express (PE / PE+)**Pump Express Plus (PE+, 2015)**

- 18-24W
- 5V - 12V
-
- D+/D-
-
-
- QC

Pump Express 3.0 (PE 3.0, 2017)

- 30W
- 3V - 6V
- **USB Type-C** Type-C
- 20 70%

USB PD PE

6.2.8 vivo FlashCharge

vivo " "

(2016)

- 22.5W
- / 9V 2.5A 5V 4.5A
-

FlashCharge 2.0

- 44W 55W 66W 120W 200W
-
- vivo

6.2.9

USB PD

(Mi Turbo Charge)

QC 3.0 (2016-2017)	-	18W (9V 2A / 12V 1.5A)	-	QC 3.0	-	5	Note 2	-		
27W (2018)	-	27W (9V 3A)	-	QC 4/QC 4+	USB PD	-	MIX 2S	8	-	QC PD

(2019-2020)

33W	-	33W (11V 3A)	-	-	-	-	-	-	9 Pro Redmi K20 Pro
50W	-	50W (10V 5A)	-	+ USB PD	-	25W	-	10 Ultra	
67W	-	67W (11V 6.1A 20V 3.35A)	-	-	11V 6.1A	-	USB PD	20V 3.35A	-
		2250mAh	-	33.5W	-	11	Redmi K40 Pro		

(2021-)

120W	-	120W (20V 6A 12V 10A)	-	-	12V 10A	-	PD	20V 6A	-	-	+	-		
2500mAh	-	MTW	-	15	4500mAh	-	11 Pro/Ultra	12 Pro						
210W	(2023)	-	210W (20V 10.5A)	-	-	100W	+	-	15C	2-3C	-	MTW	-	4
50% 9			4900mAh	-	Redmi Note 12									

- **USB PD** iPhone MacBook - **QC** QC 3.0/4+

/

```
graph LR
    A["<br/>120W"] --> B[USB-C]
    B --> C["1<br/>60W"]
    B --> D["2<br/>60W"]
    C --> E["1<br/>2500mAh"]
    D --> F["2<br/>2500mAh"]

    style A fill:#fffe1e1
    style C fill:#e1f5ff
    style D fill:#e1f5ff
    style E fill:#e1ffe1
    style F fill:#e1ffe1
```

- 34 -

80%

		PD	QC
120W	120W	65W PD	18W QC 3.0
67W	67W	45W PD	18W QC 3.0
PD	27W-45W PD	PD	QC

[!TIP]

[!NOTE] 67W

USB PD

6.2.10 (mCharge)

- 18W 24W 36W
- QC
-

6.2.11 AFC (Adaptive Fast Charging)

- 15W 18W
- 9V
- 1.67A (15W) 2A (18W)
- D+/D-
- QC 2.0 9V

[!TIP]

USB PD + PPS AFC

6.3

QC 2.0/3.0	18W		
QC 4+	100W	USB PD	PD
VOOC/SuperVOOC	20-240W		OPPO/OnePlus/realme
FCP	18W	/	
SCP	22.5-66W	/	
PE/PE+	18-24W		MTK
AFC	15-18W		QC

6.4

6.4.1

-
- 5V 1A/2A
-
- QC 2.0/3.0 9V
- QC + FCP

6.4.2

- **VOOC**

-
-

6.4.3 USB PD

[!IMPORTANT] USB PD 3.0 **PPS** Type-C
 - QC 4+ USB PD - PD - PD + PPS - **OPPO/** PD

6.4.4

- 1.
- 2.
3. **USB PD** USB PD
- 4.

6.5 USB PD (Power Delivery)

USB PD **USB-IF** Type-C

6.5.1 USB PD

- ✗
- ✗
- ✗
- ✗

USB PD

6.5.2 USB PD

D+/D- USB PD **CC** Configuration Channel

CC

Type-C CC CC1 CC2

1. Type-C
2. Source Sink
3. CC

4. PD**PD**

```
sequenceDiagram
    participant C as <br/>(Source)
    participant D as <br/>(Sink)

    Note over C,D:
    C->>D: 1. (CC )
    C->>D: 2. 5V

    Note over C,D:
    C->>D: 3. Source_Capabilities<br/>()
    Note right of D: : 5V/3A, 9V/3A,<br/>15V/3A, 20V/5A

    D->>C: 4. Request<br/>( 20V 3A)

    C->>D: 5. Accept<br/>()

    Note over C,D:
    C->>D: 6. PS_RDY<br/>()
    C->>D: 7. 20V 3A

    Note over C,D:
    D->>C: Request<br/>
```

1. Type-C CC
2. 5V
3. Source_Capabilities /
4. Request
5. Accept Reject
6. PS_RDY Power Supply Ready
- 7.

[!IMPORTANT] USB PD " " D+/D- " " PD

6.5.3 PD

USB PD CC

Source_Capabilities	Source → Sink	
Request	Sink → Source	
Accept	Source → Sink	
Reject	Source → Sink	
PS_RDY	Source → Sink	
Get_Sink_Cap	Source → Sink	
Soft_Reset	Both	PD
Hard_Reset	Both	5V

6.5.4

PD 2.0 / 3.0 (2016-2018)

- **100W** (20V 5A)
-
- 5V
- 9V 12V 15V 20V
- 5A E-Marker
-
- **45W** 5V/3A, 9V/3A, 15V/3A, 20V/2.25A - **65W** 5V/3A, 9V/3A, 15V/3A, 20V/3.25A - **100W** 5V/3A, 9V/3A, 15V/3A, 20V/5A

PD 3.1 (2021)

- **240W** (48V 5A)
- **EPR (Extended Power Range)**
- 28V 36V **48V**
-
- **EPR**

6.5.5 PPS (Programmable Power Supply)

PPS **USB PD 3.0**

PPS

PD 5V 9V 15V 20V - 9V 4.2V - 9V → 4.2V -

PPS

- 3.3V - 21V PD 3.0 PPS
- **20mV** 0.02V
-

```

graph LR
    A["PD<br/>9V"] -->| | B["4.2V"]
    C["PPS<br/>4.2V"] -->| | D["4.2V"]

style A fill:#ffe1e1
style B fill:#ffff4e1
style C fill:#e1ffe1
style D fill:#e1ffe1

Note1[<br/>]
Note2[<br/>]

```

PPS

- ⚡
- 🌡
- 💡 5-10%
- 📱

PPS

PPS

PPS		
0-30%	3.6V	3.8V
30-70%	3.9V	4.1V
70-90%	4.1V	4.3V
90-100%	4.3V	4.4V

[!NOTE] " 2.0" "PD" PPS iPhone 15 Pro PPS

6.5.6 USB PD vs

USB PD		
✓	USB-IF	✗
✓		✗
CC	D+/D-	/
" "		
240W (PD 3.1)	240W (OPPO)	
✓ PPS 20mV		QC 3.0 200mV
✓		
✓	✗	
✓		⚠

PD

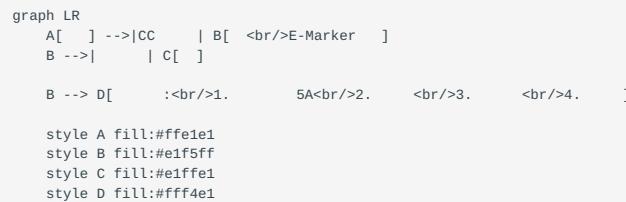
1. 2024 USB-C
 2. PPS PD
 3. PD
 - 4.
- [!IMPORTANT] OPPO **USB PD** " "

6.6 (E-Marker)

Type-C

- **3A** C-to-C 60W (20V 3A)
- **5A** **E-Marker** " 5A " 100W (20V 5A)
- **EPR** PD 3.1 240W

6.6.1 E-Marker



[!WARNING] 3A 100W 60W

6.7

6.7.1 1

66W (SCP)	Mate 40 Pro	66W	65W	SCP	
66W (SCP)	11	66W	27W	USB PD	PD
66W (SCP)	iPhone 14 Pro	66W	27W	USB PD	PD iPhone
OPPO 65W (VOOC)	OPPO Find X5 Pro	65W	65W	SuperVOOC	
OPPO 65W (VOOC)	11	65W	10W		
OPPO 65W (VOOC)	iPhone 14 Pro	65W	0W		VOOC PD
120W	12 Pro	120W	120W		
120W	iPhone 14 Pro	120W	27W	USB PD	PD iPhone
120W	MacBook Pro 14	120W	96W	USB PD	PD
140W (PD)	MacBook Pro 16	140W	140W	USB PD 3.1	
140W (PD)	12 Pro	140W	67W	USB PD	PD
140W (PD)	Mate 40 Pro	140W	27W	USB PD	PD SCP

USB PD - + PD - SCP PD - **OPPO VOOC**

6.7.2 2

11 Pro (67W) + 67W

0-50%				
6A	67W	15		
5A E-Marker	60W	17		
3A	18W	45		
	10W	70		
1	67W	15		
3	25W	35		

- - - - >60W 5A/6A

6.7.3 3

1	PD	-	Anker	-	100W / 140W USB-C PD	-	USB PD 3.0/3.1 + PPS + QC 4+ - Switch -	
2	GaN	-	Anker	-	100W / 120W	2C1A / 3C1A	-	USB PD 3.0 + PPS + QC 3.0/4+ - - Anker 747 (150W) - 100W (C1) / 100W (C2) - 100W + 50W - 65W + 45W + 40W
3		-	Baseus Ugreen	-	200W+	4-6	-	

[!TIP] **GaN** 100W GaN 1/3

6.8

6.8.1

USB BC 1.2		USB PD
(OVP)	5-10V	+
(OCP)	MCU	CC
(OTP)	/	
(SCP)	BMS +	BMS + PD
		E-Marker
		PS_RDY
		Role Swap

6.8.2

- 1.
2. USB-IF
3. USB-IF
4. " "
- 5.
6. /
7. >50°C
8. VOOC/SuperVOOC
- 9.
10. 100%
11. 80-90% " "
- 12.
13. <0°C >40°C
- 14.
- 15.

16.
17.

6.9

USB-IF	USB Implementers Forum	USB	USB
D+/D-	Data Plus / Data Minus	USB	
CC	Configuration Channel	Type-C	PD
E-Marker	Electronically Marked Cable		
MCU	Microcontroller Unit		
BMS	Battery Management System		
	Direct Charging		
	Dual-Cell Battery		
	Multi-Tab		
	Handshake Protocol		
GaN	Gallium Nitride		
PPS	Programmable Power Supply	PD 3.0	20mV
EPR	Extended Power Range	PD 3.1	28V-48V 240W
OVP	Over Voltage Protection		
OCP	Over Current Protection		
OTP	Over Temperature Protection		
SCP	Short Circuit Protection		SuperCharge Protocol
C-to-C	USB-C to USB-C	Type-C	Type-C
A-to-C	USB-A to USB-C	USB-A	Type-C

6.10

6.10.1

- USB Power Delivery Specification (USB-IF)
- USB Type-C® Cable and Connector Specification
- Qualcomm Quick Charge

6.10.2

- **POWER-Z** USB
- **ChargerLAB KT002** PD
-

6.10.3

- USB-IF
-

[!NOTE]

2023

USB-IF

7. 6

(FAQ & Common Misconceptions)

7.1 Q: Type-C

A: 1. USB 2.0 E-Marker 3A 65W/100W 2. PD
VOOC 10W 3.

7.2 Q: Type-C

A: Type-C C - **9.9** + USB 2.0 - USB 3.2 (10Gbps) + 4K + 100W - **4** 40Gbps
+ 8K + 240W Logo

7.3 Q: 65W

A: USB PD " " " 9V 2A " 18W PD 5V 1A 5V 2A

7.4 Q:

A: - 5A 4 - USB 3.2